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Statistics of the 6.7 GHz methanol maser variability from the Toruń survey

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Abstract. A sample of 174 methanol sources has been observed with the 32 m Toruń radio telescope at four or five epochs separated by 3−7 months. Observations of the 6.7 GHz maser line revealed that about 80% of sources are variable. 20% of sources showed strong variations of the integrated flux density usually on time-scales of 5−12 months. These variations were associated with strong changes in the relative intensities of maser features. Methanol emission from five sources disappeared. The time-scales of variability were longer than 12 months for only 23% of variable sources. It is suggested that the variability of methanol emission is related to the dynamics of the maser regions.

1. Introduction

The 6.7 GHz methanol masers associated with massive star-forming regions (Menten 1991) have been extensively studied over the last decade. There is, however, little information about the variability of methanol sources. With the exception of a study by Caswell, Viale, & Ellingsen (1995a) most information on variability of 6.7 GHz masers come from comparisons of data obtained with different spectral resolution and sensitivity.

Following our successful survey of IRAS selected candidates of ultracompact HII regions with the 32 m Toruń radio telescope (Szymczak, Hrynek, & Kus 2000), we started a monitoring program of a large sample of methanol masers. The data are being used to examine variability mechanisms and to select some interesting sources which deserve more extensive investigations. In this paper we report the first results of two years of observations.

2. Observations

The data were taken with the 32 m Toruń radio telescope at 4−5 separate epochs, between 1999 February and 2000 October. A dual-channel receiver with two opposite circular polarizations was used. The typical system noise was about 350 Jy. A 2^{14}−channel autocorrelation spectrometer was used. The spectral resolution was $0.04\,\mathrm{km\,s^{-1}}$. The observations were made in the total−power position switching mode. After 15 min on−source integration and averaging the two polarizations the 3σ noise level in the final spectra was about 1.6 Jy.

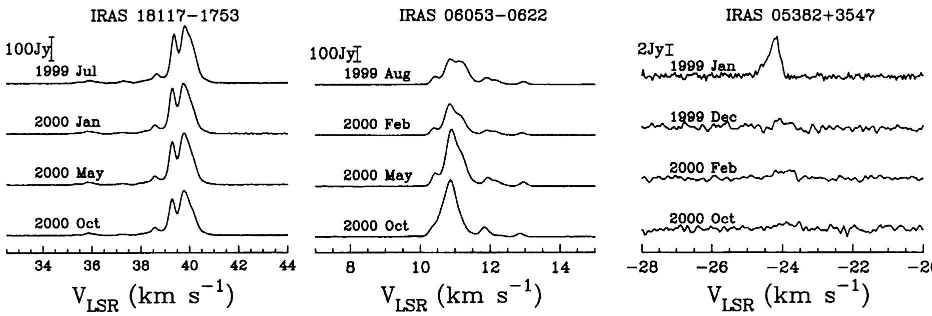

Figure 1. The 6.7 GHz methanol maser spectra of three typical sources at four epochs.

The continuum sources 3C123 and Vir A were used as flux density calibrators. The absolute flux density of individual spectra has uncertainties of less than 10%. More on the telescope equipments and observational procedures were described by Szymczak et al. (2000). A sample of 174 methanol maser sources was monitored. This contains nearly 96% of detections made in a comprehensive search for the 6.7 GHz methanol maser line from IRAS selected candidates of ultracompact HII regions (Szymczak et al. 2000).

3. Results

Spectra of three typical sources taken at four epochs are shown in Fig. 1. *18177−1753* is an example of non-variable source. Its profile shape and flux density of individual features were stable over a period of 16 months. We note that our spectra are very similar to those reported by Caswell et al. (1995b), thus it is likely that the source does not vary on a time-scale of 8 years. *06053−0622* showed strong variability. The feature at 10.8 $km\,s^{-1}$ increased in amplitude by more than a factor of two during 14 months. The methanol emission from *05382+3547* was detected only at one epoch, then its flux density decreased below our sensitivity limit of 1.6 Jy. Maser emission disappeared completely from 5 sources, listed in Table 1. In three sources shown in bold in table 1, the emission dropped below our 3σ limit at least once. The decay time of maser emission (Δt) ranged from 5 to 21 months.

IRAS	Δt (month)	IRAS	Δt (month)
05382+3547	21	18193−1411	6
06061+2151	15	18305−0758	14
18111−1729	9	**19012+0505**	11
18141−1626	9	**19189+1520**	5

Table 1. Strongly variable sources which methanol maser emission dropped below 1.6 Jy.

To quantify the variability of masers we calculated the variability index (VI) defined as

$$VI = \frac{1}{n\langle S\rangle} \sum_{i=1}^{n} |S_{int,i} - \langle S\rangle|$$

where $S_{int,i}$ is the integrated flux density at epoch i and $\langle S\rangle$ is the integrated flux density averaged over n epochs. The ratio of the integrated flux densities at maximum and minimum (S_{max}/S_{min}) and the time span between maximum and minimum were calculated. To avoid errors in the flux scale affecting our estimates of variability we calculated the relative flux densities of maser features for each source.

The distribution of the variability index in our sample of 174 sources is shown in Fig. 2 (left). 20% of sources in the sample do not show variations (VI <0.12) within our measurement accuracy. Small variations with 0.12< VI ≤0.20 were observed in 34% of the sources. Moderate variability with 0.20< VI <0.36 occurred in 26% of the sources. 20% of the sources exhibited strong variations with VI >0.36.

The time-scale of variability was estimated as the time between maximum and minimum of the integrated flux density. Distributions of time-scales for four groups of the sources are shown in Fig. 2 (right). Note that 35 non-variables sources are not considered. The first group contains 35 sources with the peak flux density below 6 Jy. The methanol emission from these sources was observed at all epochs but the estimates of variability may be less certain. A group of 31 weakly variable masers with VI <0.19 and S_{max}/S_{min} <1.9 varied on time-scales of 2−19 months. Typical time-scales of variability of 36 sources with moderate variability (0.2< VI <0.36) were 4−12 months. In this group the number of sources with long time-scales of variability gradually decreased. 26 out of 37 strongly variable sources characterized by VI >0.36 varied on time-scales of 4−12 months. In the latter group almost all sources showed significant changes in the relative flux densities of individual maser features. Our maser sources usually varied on time-scales shorter than 12 months. There was only 23% of sources which changed on longer time-scales (Fig. 2 right).

4. Discussion

This study provides the statistics of the 6.7 GHz maser emission variability on time-scales of 4−19 months for a large sample of sources. We found that about 80% of masers are variable. 20% of sources show strong variability with VI >0.36 and strong variations of peak flux densities and/or intensity ratios of individual features which are commonly higher than 30%. The percentage of strongly varying methanol sources in a sample analyzed by Caswell et al. (1995a,b) is similar to ours. This similarity is partly a result of the inclusion of about half of our sample in the survey by Caswell et al.. However, when we consider only the sources not listed by them, the percentage of strongly variable sources is still the same. Moreover this percentage is only slightly higher than a crude estimate of 15% from previously published data (Szymczak et al. 2000). Therefore, we conclude that about 20% of the 6.7 GHz methanol masers experience strong vari-

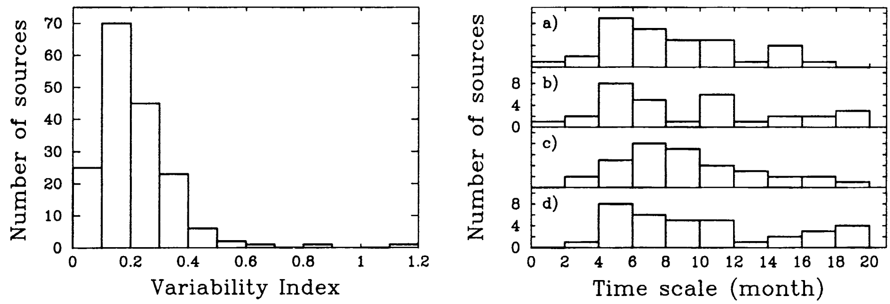

Figure 2. Left: Variability index for the sample of 174 methanol maser sources. Right: Time-scales of variability for four groups of methanol sources; a) sources with the peak flux density <6 Jy, b) weakly variable, c) moderately variable, d) strongly variable.

ability on time-scales of 4−19 months. In the group of strongly variable sources there are 8 objects where methanol emission dropped below the sensitivity limit; 5 of them disappeared completely as maser sources. This suggests that when the survey of our original sample of IRAS objects is repeated methanol emission will be detected from an additional ~5% of sources at other epochs.

Long-term variability of on time-scales of months is likely to be intrinsic to these methanol masers. Observations of several sources show that OH and CH_3OH maser transitions are spatially coincident and have similar velocity structure on scales smaller than 500 au (e.g. Menten et al. 1992). If the variability is related to the dynamics of the regions in which maser conditions are sustained, one can expect that OH and CH_3OH masers would vary in similar manner. In our sample there are at least two well known sources with well-documented OH maser variability. *02232+6138* (W3(OH)) shows no substantial variations in the OH lines at 1.6 GHz over 30 years. This source is also non-variable in the 6.7 GHz methanol line. *06053−0622* (Mon R2) is a strongly variable methanol source which also shows prominent variations at several OH transitions. We suggest that the variations of methanol sources on time-scales of months are related to the dynamics of the maser regions.

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